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OBSERVATIONS AND SIMULATIONS OF THE M–I COUPLING OF BURSTY CONVECTION

SRI Project P10055

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1 INTRODUCTION

This annual report summarizes the progress achieved in the second year of NASA Grant NAG5-8111, "Observations and Simulations of the M-I Coupling of Bursty Convection."

The ultimate aim of the project is to establish how much of the magnetotail's total potential is due to flow bursts and how much of this potential maps to the ionosphere. In order to quantify these contributions, we further developed a method to measure the total cross-polar cap potential and the total reconnection rate across the entire polar cap boundary. Then we applied the method to different solar wind–magnetosphere–ionosphere conditions that included substorm periods, storms, and steady magnetospheric convection (SMCs, also known as convection bays) periods. In the following section, we describe in more detail the activities during the second year of this grant.

2 ACTIVITIES

We applied the reconnection algorithm developed in the first year to several periods sampling diverse solar-terrestrial conditions, including steady magnetospheric convection, substorms, and storms.

The algorithm consists of the following steps:

(1) Subauroral pixels are identified in calibrated UVI LBHL images by a first order guess of the oval equatorward boundary
(2) A linear fit is performed of the subauroral data numbers versus the calculated solar elevation angle on an individual image-by-image basis
(3) Estimated solar contribution is subtracted for each image
(4) Images are mapped onto a PACE geomagnetic coordinate grid
(5) The high latitude boundary of the auroral oval is determined at a brightness threshold of 4.8 photons cm^{-2}/s^{-1} [Baker et al., 2000]

The polar cap boundary is determined as the periodic curve that fits the locii of the specified brightness threshold. With the curve defined, the orientation and velocity of the polar cap boundary can be quantified at each point. The next step is to measure the electric field distribution in the ionosphere, which is determined from incoherent scatter and SuperDARN radar measurements. Since radar measurements generally do not cover the entire area of the polar cap and auroral oval, they are complemented with the assimilative mapping of ionospheric electrodynamics (AMIE) technique, which is then used to fill the gaps in electric field measurements.

Given the knowledge of the polar cap boundary orientation and velocity and the electric field at every point, the calculation of the local reconnection electric field in the frame of reference of the polar cap boundary is straightforward and given by the relationship

$$\underline{E}_{rec} = \underline{B} \times (\underline{V}_n - \underline{U}_n) \quad ,$$

where $\underline{V}_n$ is the ionospheric plasma flow normal to the polar cap boundary, $\underline{U}_n$ is the normal velocity component of the polar cap boundary, and $\underline{B}$ is the ambient magnetic field in the ionosphere. With the electric field defined in the field of reference of the polar cap boundary, we can then determine the net rate of magnetic flux transfer across the polar cap boundary by simply integrating the component of the electric field tangent to the boundary.

Figure 1 shows a sequence of POLAR UVI LBHL images during a substorm period on February 14 and 15, 1998. The expansion phase of the substorm was accompanied by an expanded oval with latitudinally elongated nightside auroral arcs in the pre-midnight local time sector. Geotail, located in the same region, observed intense bursty bulk flow activity. The Sondrestrom incoherent scatter radar was sampling the poleward region of the arcs, and Geotail's footpoint (mapped with T89, Kp=3) was embedded in the equatorward region. The net negative integrated reconnection potential (-19 kV at 0137:45 UT, as shown in Figure 2) indicates a predominance of nightside reconnection over dayside merging during the period of expanded plasma sheet and intense bursty bulk flow activity. The expansion of the auroral oval started at 22:30 UT and progressively intensified until approximately 23:45 UT, as shown by the negative slope in the green line of the top panel in Figure 3. As the oval expanded, nightside reconnection intensified, as shown by the green trace in the middle panel of Figure 3.

Figure 4 shows a full oval view typical of an SMC period on 3–4 February 1998. SMCs are also known as "convection bays". During this event the IMF was southward for 12 hours, starting at 13 UT on 3 February. The nightside reconnection region spanned 8 hours local time, and the net reconnection potential along the polar cap boundary was –8.4 kV. After 23:15 UT nightside reconnection became greatly enhanced, producing negative total potential values. Figure 5 shows a comparison of dayside versus nightside polar cap area. The nightside polar cap area between 16:00 UT and 1709:04 UT increased (equivalent to a flux rate of 2.3×10^4 Wb/s); afterward, the total polar cap area was on average smaller, although there was a weak nightside inflation of 1.5×10^4 Wb/s followed by a weak deflation of -5.3×10^3 Wb/s. There was a weak dayside inflation of 5×10^3 Wb/s after 18:45 UT. The total area decreased again after 20:45 UT, although there was a sustained dayside inflation of 2.2×10^4 Wb/s that lasted until 00:30 UT on 4 February. During the same period there was nightside inflation of 1.7×10^4 Wb/s, followed by sustained deflation of -2×10^4 Wb/s. The nightside area started to increase again at 00:30 UT until it reached a maximum of 5.0×10^6 km^2 at 01:20 UT. Nightside deflation started at that time.

The following is a summary of our efforts and findings:

- We combined POLAR images and ground-based measurements of convection to calculate the rate of magnetic flux loading and unloading of the magnetosphere for various magnetospheric responses to solar wind input

- The SMC period (3–4 February 1998) had significant power delivered by the solar wind over nearly 12 hours. However, the magnetic flux in the polar cap remained small. Weak inflation and deflation was apparent every ~3 hours. Significant loading started only 3.5 hours before a substorm onset, after a change in IMF B$_y$ from +5 nT to –10 nT

- The solar wind power delivered during the substorm period (14–15 February 1998) was 50% lower than during the 3–4 February period. However, the loading was 40% higher

- In both examples, the nightside reconnection potential, or equivalently the polar cap deflation rate, was greatly enhanced as the plasma sheet expanded

- The plasma sheet expansion is correlated with a widening of the reconnection region at the nightside polar cap boundary

A manuscript to be submitted to the *Journal of Geophysical Research* is currently undergoing review by the coauthors. The title of the manuscript is "Global measurements of reconnection and its relationship to magnetotail transport," E.R. Sánchez, R.A. Doe, SRI International; K. Liou, S. Shepherd, JHU/APL; G. Parks, University of Washington; T. Mukai, Y. Saito, ISAS; and G. Blanchard, Louisiana Tech.

3 PLAN FOR COMING YEAR

During the third year of this grant, we will complete a study of the global merging and reconnection properties for various solar wind–magnetosphere-ionosphere conditions. Also, we will isolate, for the same examples, the electric field and current signatures of the ionospheric regions that map to bursty bulk flows observed by GEOTAIL. We will quantify the reconnection potential relative to bursty bulk flows and compare it with the total measured potential. We will apply the merging and reconnection algorithm and the identification of ionospheric electrodynamic properties of bursty bulk flow signatures to additional cases.

4 REFERENCE

Baker, J. B., C. R. Clauer, A. J. Ridley, V. O. Papitashvili, M. J. Brittnahcer, and P. T. Newell, "The nightside poleward boundary of the auroral oval as seen by DMSP and the Ultraviolet Imager," *J. Geophys. Res., 105*, 21267, 2000.
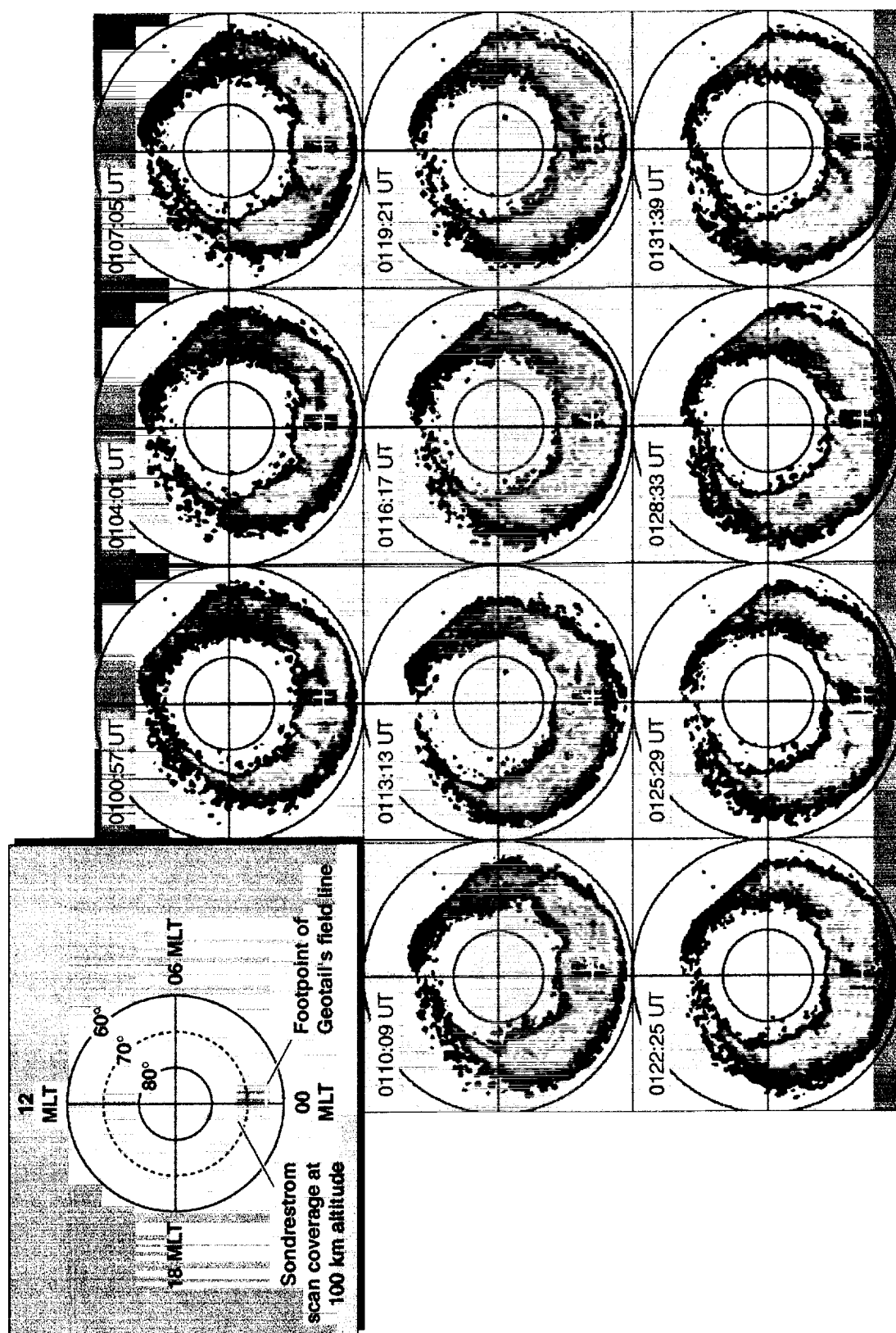
Figure 1. Sequence of POLAR UVI LBHL images showing an expanded oval with latitudinally elongated arcs during a period of intense bursty bulk flow activity (14–15 February 1998).
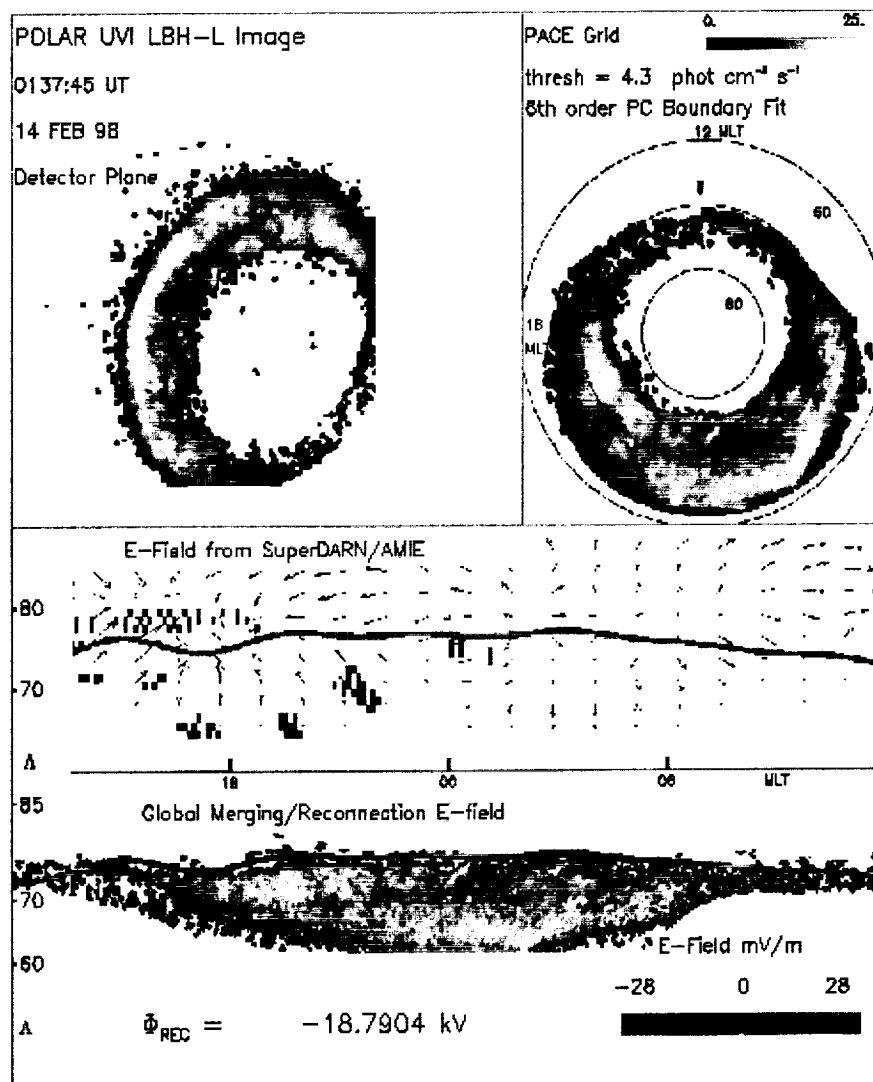
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Figure 2. Polar UVI LBHL Images. The upper left panel shows the detector plane of the UVI instrument. The upper right panel shows the image after correction for scattered sunlight and geomagnetic projection. Superimposed is a fit to the location of the polar cap boundary. The middle panel shows this boundary projected on a two-cell ionospheric electric field distribution. The bottom panel shows the magnitude of the reconnection electric field along the polar cap boundary. Red shades indicate positive electric field (net plasma flow into the polar cap) and blue shades ndicate negative values (net plasma flow from the polar cap).
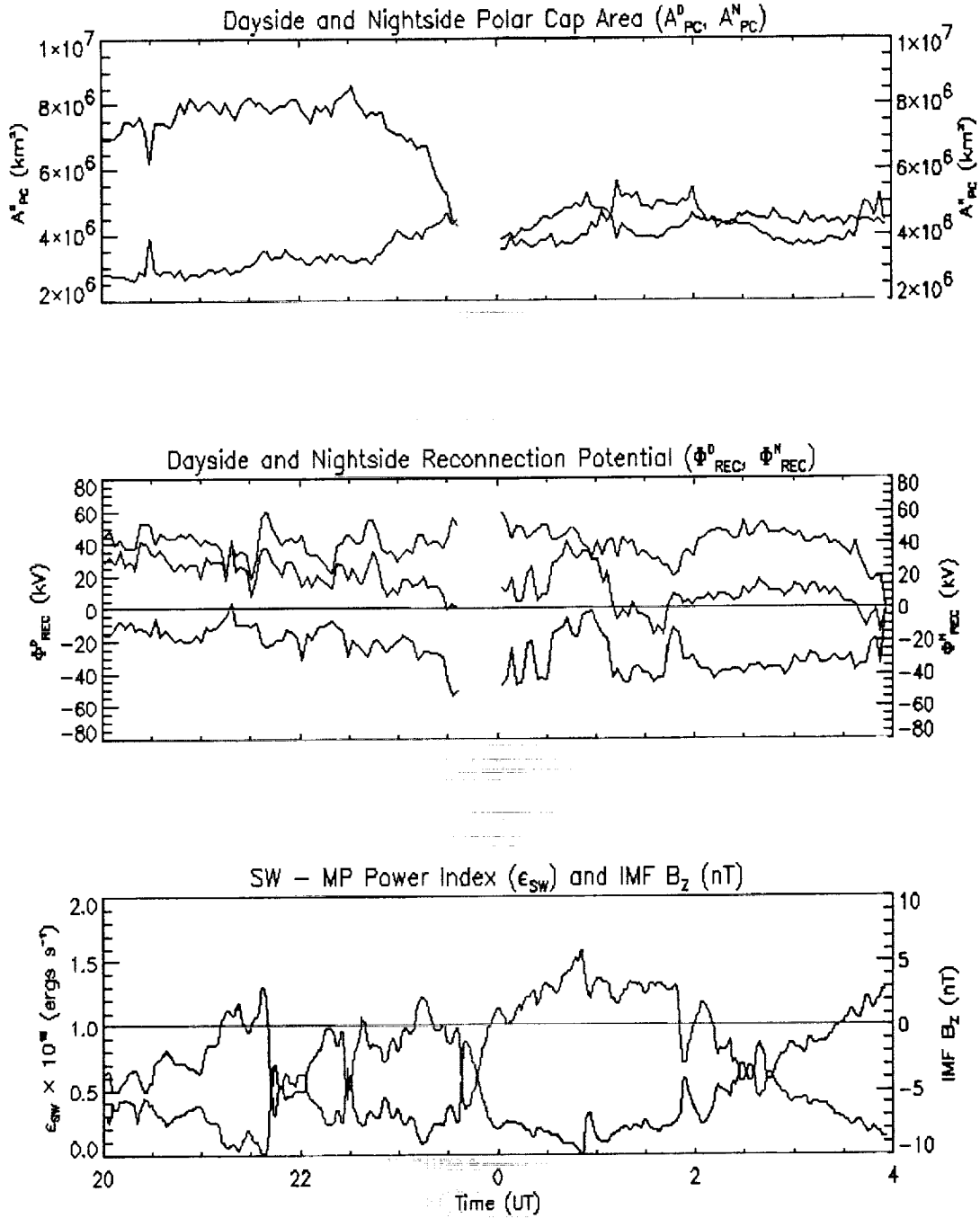
Figure 3. Evolution of polar cap area (top panel) and reconnection potential (middle panel) relative to solar wind IMF Bz orientation (red trace at bottom panel) and solar wind energy flux intercepted by the magnetosphere ("epsilon" parameter, shown by black trace). Blue traces in the top two panels correspond to parameters integrated over the dayside region, green traces correspond to calculations in the nightside region.
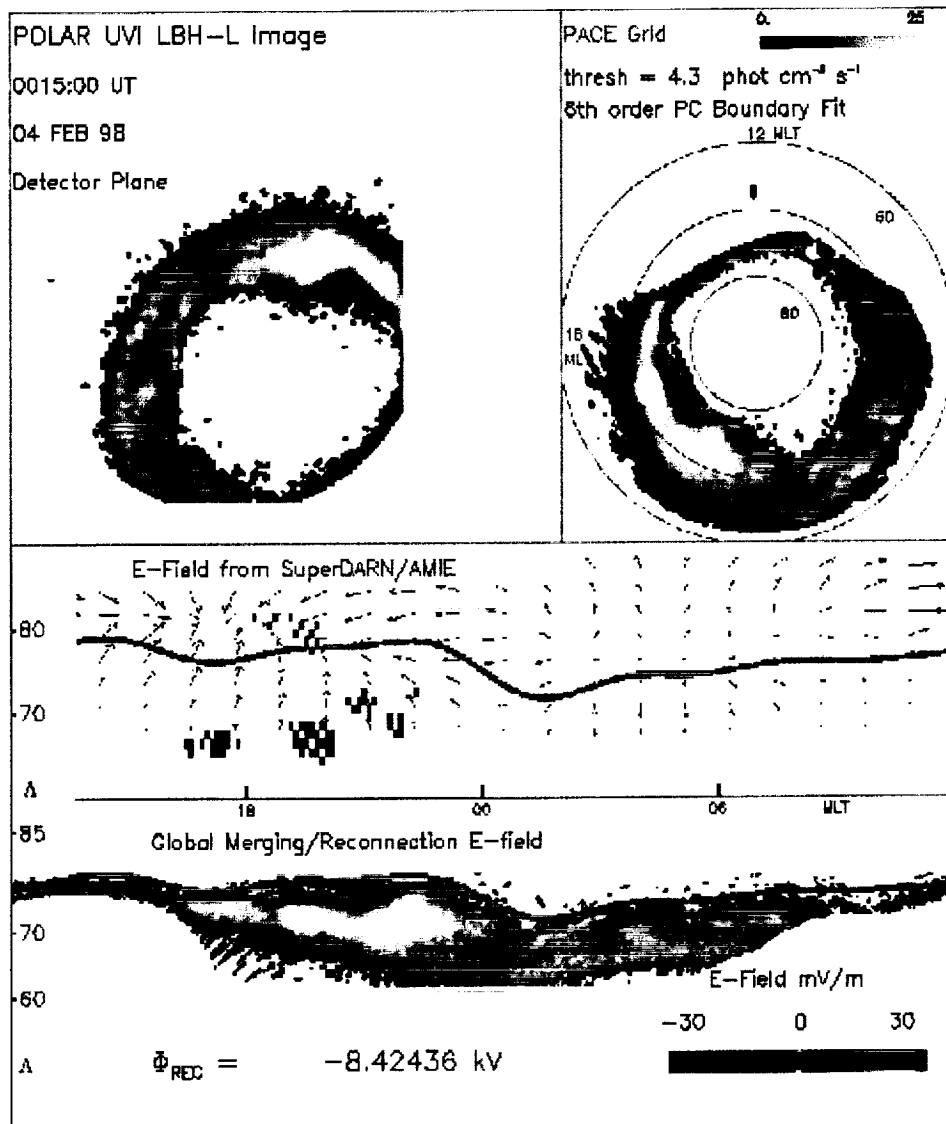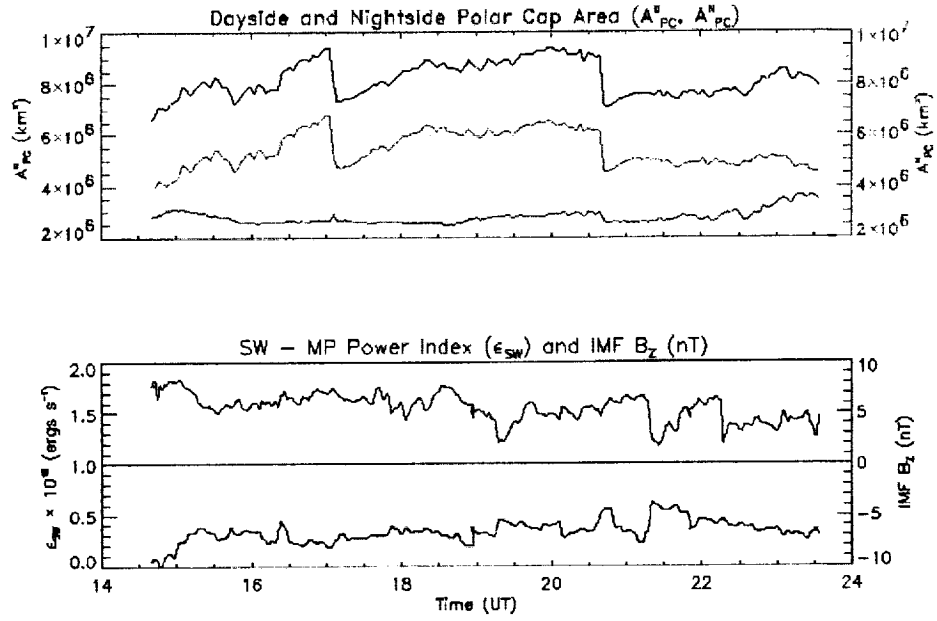
Figure 4. Global reconnection potential during an SMC period.

03 February, 1998

Dayside and Nightside Polar Cap Area (A^D_{PC}, A^N_{PC})

SW — MP Power Index (ϵ_{SW}) and IMF B_z (nT)

04 February, 1998

Dayside and Nightside Polar Cap Area (A^D_{PC}, A^N_{PC})

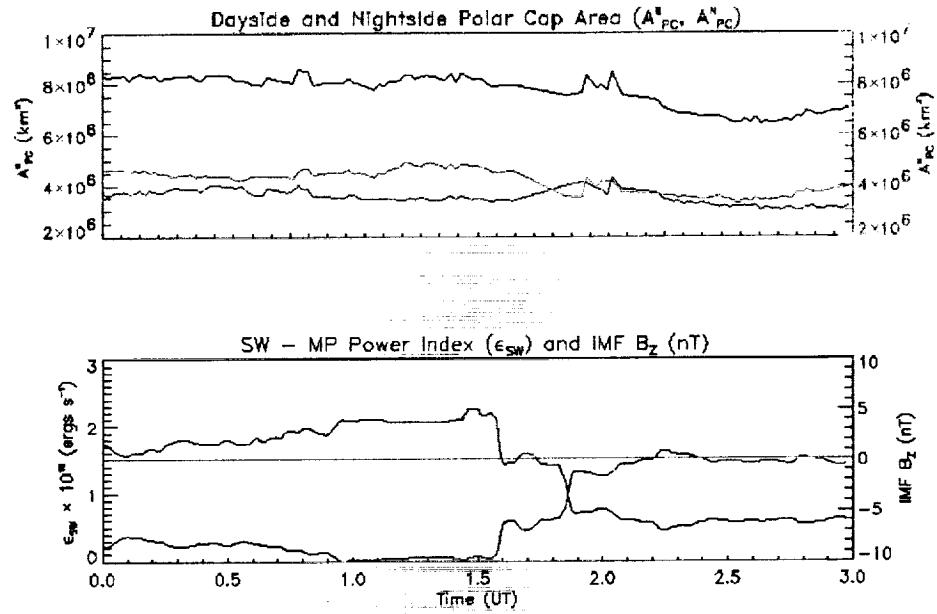SW — MP Power Index (ϵ_{SW}) and IMF B_z (nT)

Figure 5. **Evolution of polar cap area (first and third panels) relative to solar wind IMF Bz orientation (red trace at second and fourth panels) and solar wind energy flux intercepted by the magnetosphere ("epsilon" parameter, shown by black trace at same panels).** Blue traces correspond to dayside polar cap area, green traces correspond to nightside polar cap area.

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